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ABSTRACT

Many high school and college students experience serious difficulties in understanding as well as applying fundamental concepts in physics. The study reported in this paper focused on the difficulties in learning about vectors in physics and strategies for making the teaching of vectors more interesting and meaningful for students. Specifically, the study aimed at: developing instructional materials for linking the notion of vectors, especially composition of vectors and resolution of a vector, with the real Physics world; planning appropriate demonstrations in conjunction with the Prediction-Demonstration-Explanation (PDE) teaching method to highlight the meaningful applications of the notion of vectors in daily phenomena as well as to make the learning of vector concepts and rules more interesting for students; and exploring the effectiveness of the use of the PDE method in helping students grasp the notion of vectors. The sample consisted of 94 junior college students divided into an experimental and a control group who took pre- and post-tests. The results indicate that students in the experimental group, who were taught by the Prediction-Demonstration-Explanation method, showed a better improvement in performance on the tests than students in the control group. (JRH)

LEARNING DIFFICULTY IN APPLYING NOTION OF VECTOR IN PHYSICS AMONG "A" LEVEL STUDENTS IN SINGAPORE

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Introduction

Many high school and college students experience serious difficulties in understanding as well as applying fundamental concepts and principles in physics (Karplus, 1981; McDermott, 1982). In areas such as Mechanics, students' interpretations of observed phenomena are frequently found to be incorrect and significantly different from the scientific ideas (Green, McCloskey & Caramazza, 1980; Trowbridge & McDermott, 1980, 1981;Clement, 1982). At the Pre-University level, students experience difficulty in assimilating the properties of vector (Aquirre and Erickson, 19'4). Analysis of the difficulties faced by the students indicates that they use the vector notation devoid of physical meaning. They have not incorporated the notion of vector into everyday physics phenomena. In this article, we focus our attention on the difficulties in learning vector in physics. In order to make the

teaching of vectors more interesting and meaningful for students as well as to help them grasp the notion of vector and its applications in everyday experiences, we adopted the demonstration-observation-explanation teaching method. Simple but useful apparatus were used to perform simulated demonstrations of physics phenomena.

PURPOSE OF STUDY

The study is aimed at:

(A) developing instructional materials for linking the notion of vectors, especially composition of vectors and resolution of a vector, with the real Physics world;

(B) planning appropriate demonstrations in conjunction with the Prediction-Demonstration-Explanation teaching method to highlight the meaningful applications of the notion of vector in daily Physics phenomena as well as to make the learning of vector concepts and rules more interesting for students; and

(C) exploring the effectiveness of the use of the P.D.E. method in helping students grasp the notion of vector.

DESIGN OF THE STUDY

(A) Implementation of the Study

The areas of study included vector-addition, vector-subtraction and resolution of a vector. 94 Junior College students were involved in this study. The sample consisted of 45 students of the experimental group and 49 students of the control group. The experimental and control groups both consisted of 3 tutorial groups each and were selected randomly from 14 groups of first year Pre-University students. The same Pre- and post-test (Annex 1) was designed to identify learning difficulties in the selected areas as well as to analyse the improvement in learning after the students underwent the different programs. Each item on the test consisted of two parts. The first part was a multiple-choice question based on common learning difficulties of students from our past teaching experiences. The second part of the item required the students to give their reasons pertaining to the answer which they had chosen. The duration of the study was 4 weeks with each week consisting of a double-period of about 1½ hours.

(B) Teaching Unit

The role of motivation in the classroom is described as

a process of arousing, maintaining and controlling interest. Motivation certainly helps teachers to establish an appropriate classroom environment for students that facilitates effective learning. In this study, the method we employed to stimulate curiosity, interest and enjoyment is to provide the students with interesting demonstrations which also include sequent questions to promote thinking. We believe that a well-planned demonstration can be used to arouse and sustain motivation, interest and curiosity as well as to explain the concepts clearly to the students. The Predict, Demonstrate and Explain Tasks was adopted as the main teaching method in this study. The PDE Tasks consists of 3 stages.

(a) Describe to the students the situation or show them the experimental set-up, and ask the students to predict what will happen.

(b) Demonstrate the experiment and ask the students to observe carefully and to take notes.

(c) Challenge the students to explain/defend their predictions and discuss any conflicts between their predictions and their observations.

The key concepts/rules and their applications in Physics are summarized in Figure 1. For a more detailed demonstration plan, please refer to Annex 2.

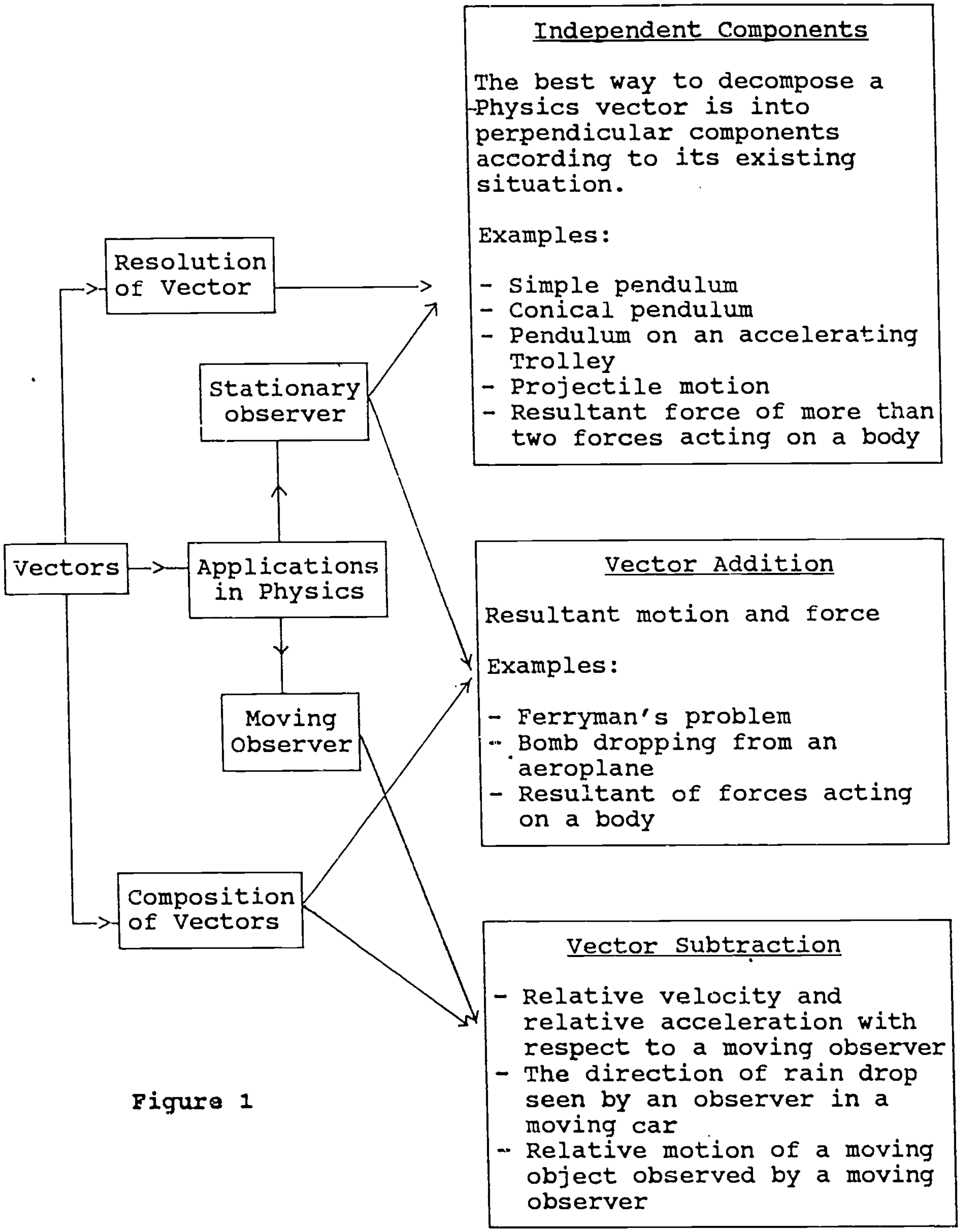

Vectors
Resolution of Vector
Applications in Physics
Stationary observer
Moving Observer
Composition of Vectors
Independent Components
The best way to decompose a Physics vector is into perpendicular components according to its existing situation.
Examples:
- Simple pendulum
- Conical pendulum
- Pendulum on an accelerating Trolley
- Projectile motion
- Resultant force of more than two forces acting on a body
Vector Addition
Resultant motion and force
Examples:
- Ferryman's problem
- Bomb dropping from an aeroplane
- Resultant of forces acting on a body
Vector Subtraction
- Relative velocity and relative acceleration with respect to a moving observer
- The direction of rain drop seen by an observer in a moving car
- Relative motion of a moving object observed by a moving observer

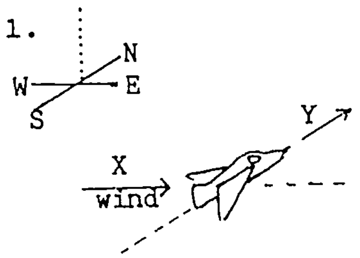
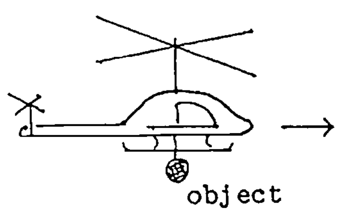
Figure 1

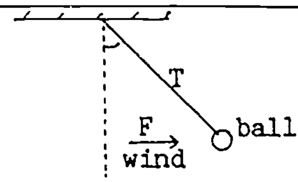
RESULTS AND DISCUSSION

Based on the analysis of the results of the Pre-test and Post-test, the discussion is separated into two main sections.

(A) In the first section, we try to identify the possible learning difficulties so that a suitable teaching package can be prepared. The main learning difficulties concerning the learning of the topic and its application are summarized as follows:

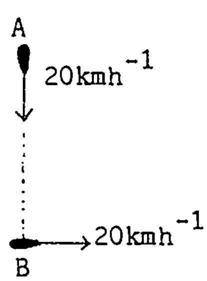
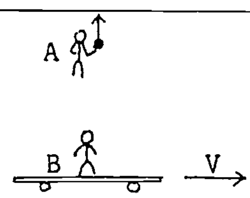
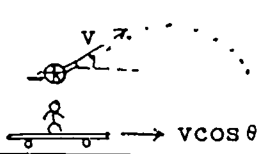
ADDITION OF VECTORS

1. 	About 65% of the students answer correctly this item. For those who answer the item wrongly, there is no significant number of students giving a particular incorrect answer.
2. 	Many students (~70%) think that the object will drop vertically down upon release. They have not considered the resultant velocity of the object has two components: (a) the vertical component due to gravity, and (b) the horizontal component v due to the velocity of the helicopter (Newton's First Law).

3.		About 43% of the students answer this item incorrectly. Among them, most students select the option T = W + F

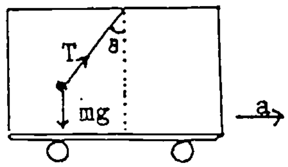
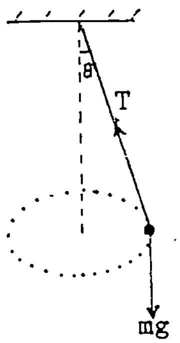
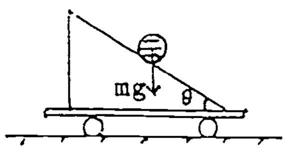
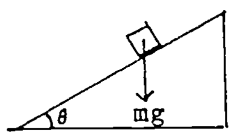
It seems that students do have some difficulties in applying the notion of addition of vectors in solving some physics problems.

SUBTRACTION OF VECTORS

4.		There is quite a number of students (56%) thinks that the path of B observed by A still along the same direction. They fail to visulize that the path of B as observed by A would be different since A is also moving.
5.		More than half of the students (51%) feel that man A and the ball move forward since man B is moving forward.
6.		Most of the students (54%) thinks that the moving observer still see the same parabola.

This indicate that most of the students fail to imagine the relative motion as observed by a moving observer.

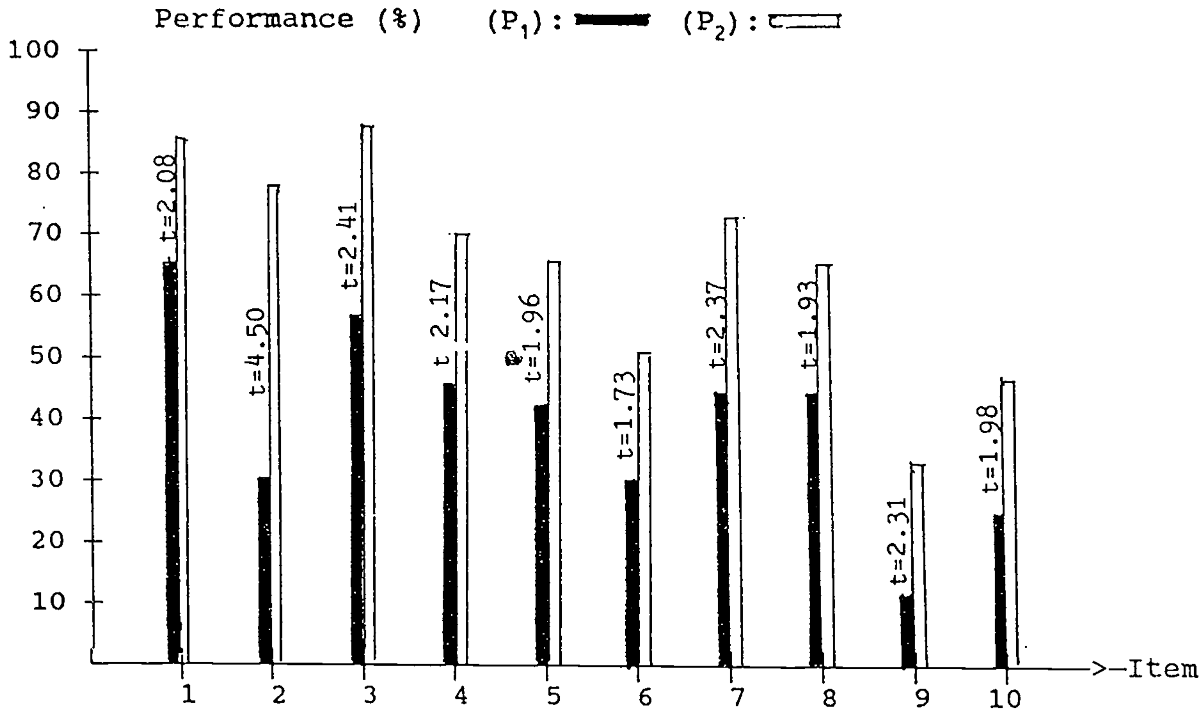
RESOLUTION OF VECTOR

7. 	Quite a number of students (50%) choosing mgcosθ as the tension. Students decomposed mg instead of T.
8. 	There is a significant number of student (48%) who think that T = mg cosθ + centripetal force. This reflects that students have decompose the mg wrongly as well as do not know that the two forces, mg cosθ and centripetal force, are not pointed the same direction.
9.  10. 	Many students (~72%) think that the accelaration along the horizontal direction is zero since the gravitational force mg (vertically downward) does not have the horizontal component.

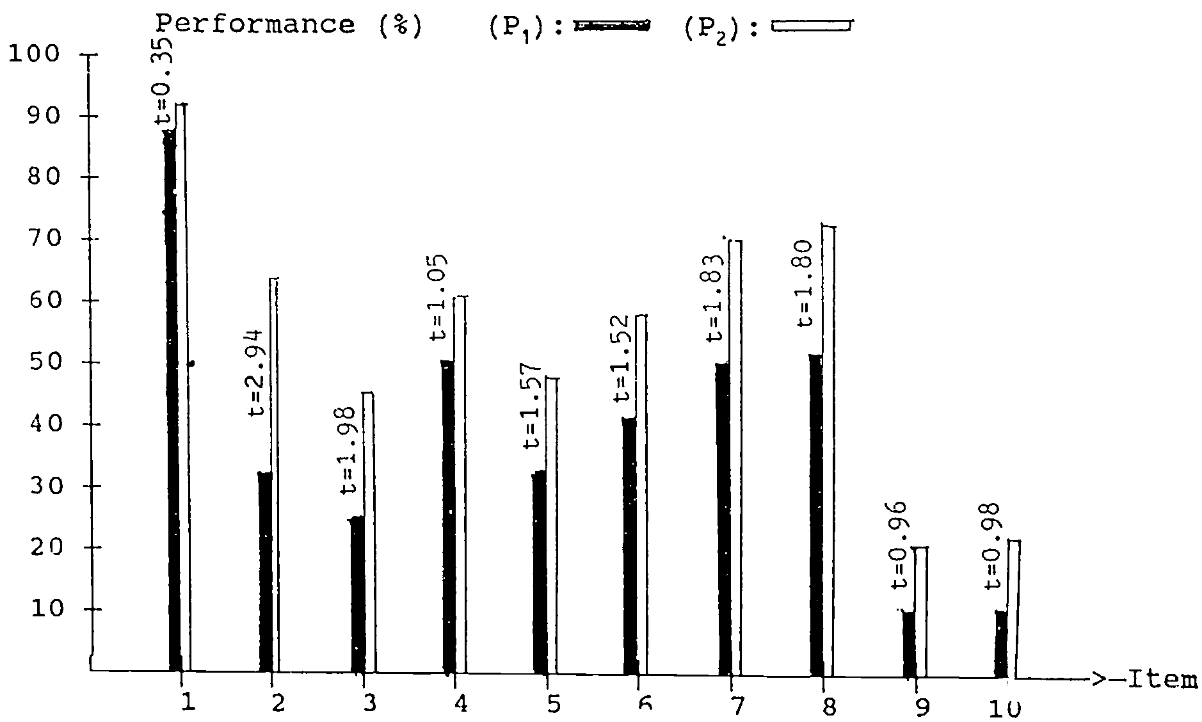
on the whole, students have the difficulties to decise which force should be resolved. They do not know that resolution of a vector (force) depends on the dynamics motion of the situation under consideration.

(B) Comparations of the results of the Post-test with Pre-test for experimental and control groups are shown in the Figures below.

Comparation of the performance of students in the experimental group in the Post-Test (P_2) to that of the Pre-Test (P_1) with level of confidence of the improvement (t).



Comparation of the performance of students in the control group in the Post-Test (P_2) to that of the Pre-Test (P_1) with level of confidence of the improvement (t).



There is a general improvement of scores for both groups but there are still about an average of 30% to 40% of students give the incorrect answers in the Post-test in most of the areas. However, the students in the experimental group, who have undergone the treatment through Prediction-Demonstration-Explanation method, have shown a better improvement in performance than the students in the control group. To improve the study further, we should put more effort in analysing students' prior knowledge as well as to design activities to enable students have the first-hand experiences instead of just observing the demonstrations.

REFERENCE

1. Aquirre J. and Erickson, G. (1984). Students' Conceptions About The Vector Characteristics of Three Physics Concepts. Journal of Research in Science Teaching, Vol 21, No 5, p 439-457.

2. Beck, R. (1978). Motivation Theories and Practice Prentice-Hall Inc.

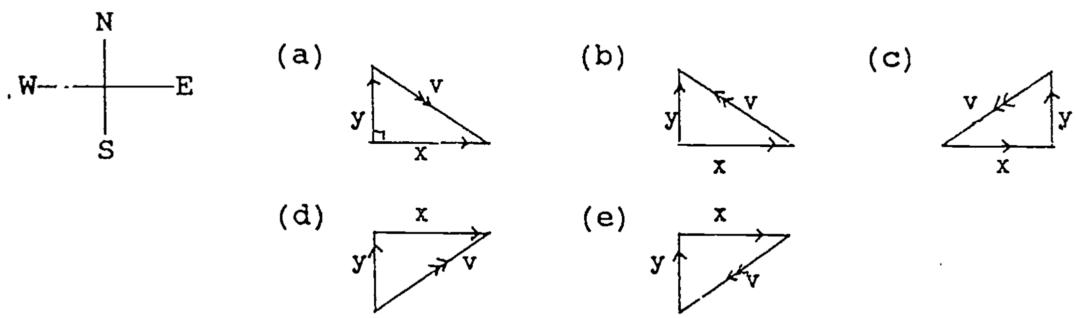
3. Cunter Lind. (1982). The structure of interest in Physics. European Journal of Science Education, Vol 4, No 3, p 275-283.

Annex 1

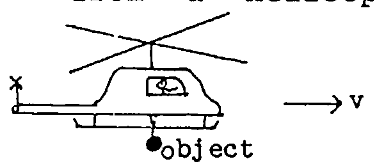
Multiple-Choice Questions

(Give reasons for your selected answer on a separate sheet.)

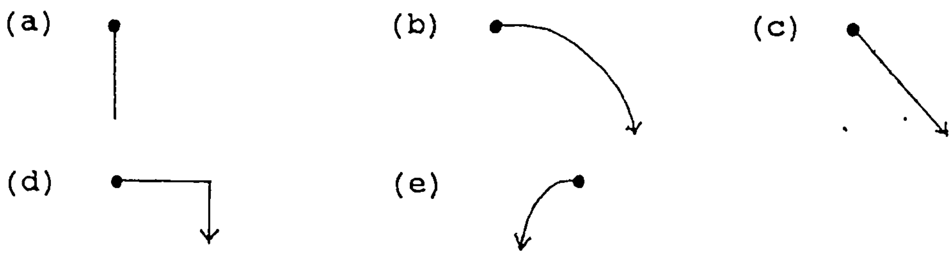
1. An aircraft moves with constant velocity at y m/s due north. A strong wind blows horizontally at x m/s due east. Which one of the diagrams represents the resultant velocity of the aircraft?



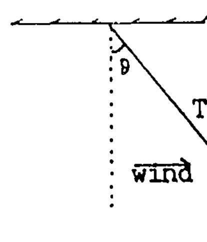
2. An object is dropped from a helicopter flying horizontally.



Which one of the diagrams below is the path of the object observed by a man standing on the ground directly below it initially.



3. A small ball of weight, W is suspended by a light thread. When a strong wind blow horizontally, exerting a constant force, F on the ball, the thread makes an angle, θ to the vertical. What is the tension (T) in the string?



(a) $T = F \sin\theta + W \cos\theta$

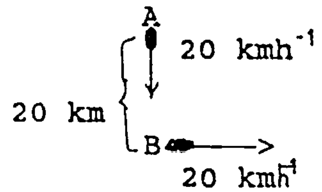
(b) $T = \dfrac{W}{\cos\theta}$

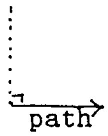
(c) $T = W \cos\theta$

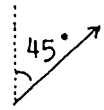
(d) $T = W + F$

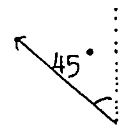
(e) $T = W$

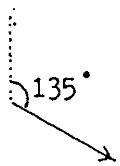
4. Two ships A and B are 20 km apart and both moving with velocity of 20 kmh^{-1} as shown. Which one of the following diagrams shows the path of ship B observed by observer in ship A?

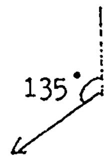


(a) 

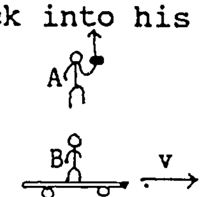
(b) 

(c) 

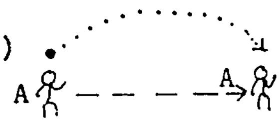
(d) 

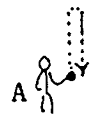
(e) 

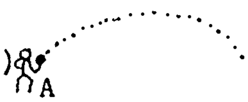
5. Man A throws a stone vertically into the air and allows it to fall back into his hand.

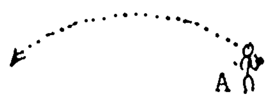


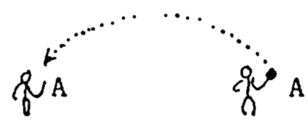
The observation on man A and the stone as seen by a moving observer B can be illustrated correctly by diagram.

(a) 

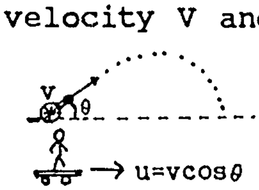
(b) 

(c) 

(d) 

(e) 

6. A ball is projected with the initial velocity V and the elevation angle θ. Which one of the following diagrams shows the path of the ball as observed by the moving observer B?

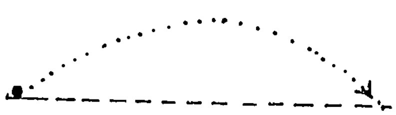


(a) 

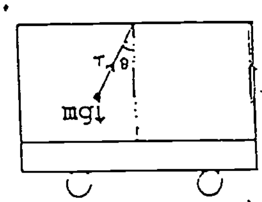
(b) 

(c) 

(d) 

(e) 

7. A pendulum hangs down from the roof of a carriage



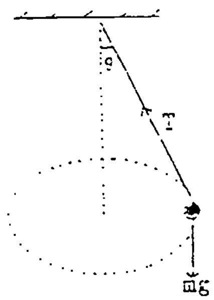
---> a (acceleration)

makes an angle of θ with the vertical when the carriage is accelerating. The tension, T in the string is

(a) $\frac{a}{g}\cot\theta$ (b) $mg/\cos\theta$ (c) $mg\cos\theta$

(d) $\frac{a}{g}\tan\theta$ (e) mg

8. A bob is suspended by a string and made to go round horizontally in a circular motion. The tension in the string is

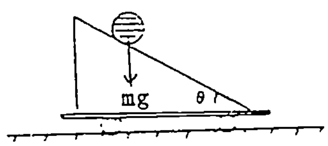


(a) mg (b) $\frac{mg}{\cos\theta}$

(c) $mg\cos\theta$ (d) $mg\sin\theta$

(e) $mg\cos\theta$ + centripetal force

9. When a ball is rolling down an inclined plane which is fixed on a trolley as shown, the trolley will



(a) remain at rest

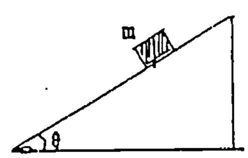
(b) move to the right at constant velocity

(c) move to the left at constant velocity

(d) accelerate to the right

(e) accelerate to the left

10. A block of mass m moves down along, an inclined plane. Assuming frictionless contact, find the acceleration of the block along the horizontal direction.



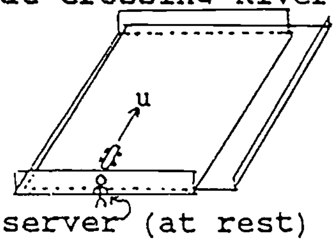
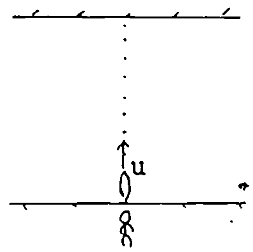
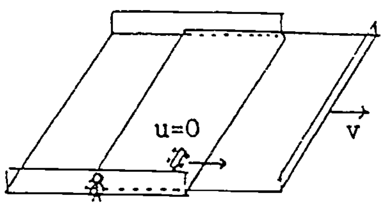
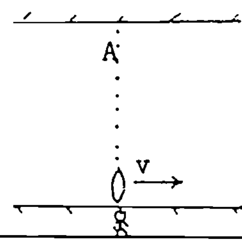
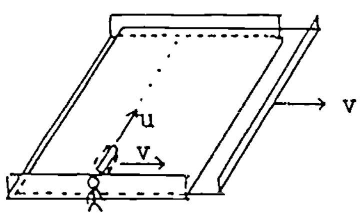
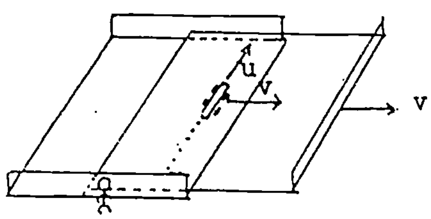
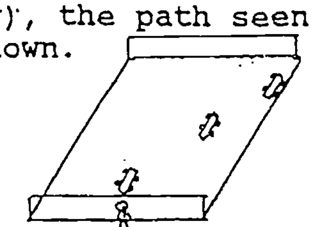
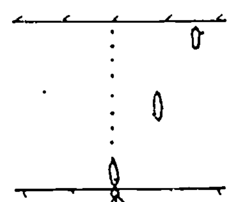
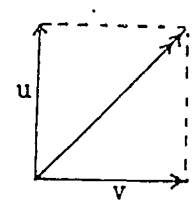
(a) zero (b) g

(c) $g\sin\theta\cos\theta$ (d) $g\sin^2\theta$

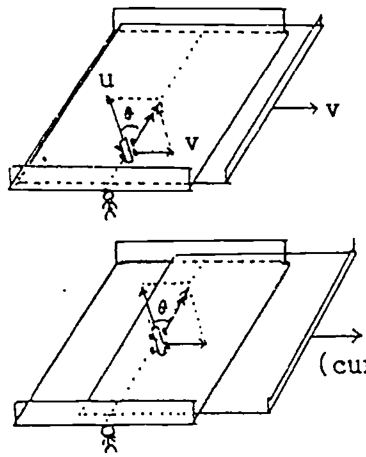
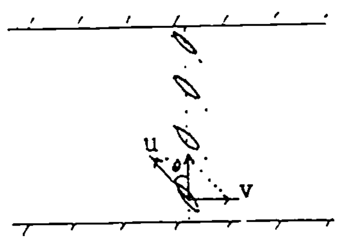
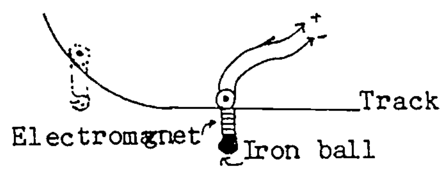
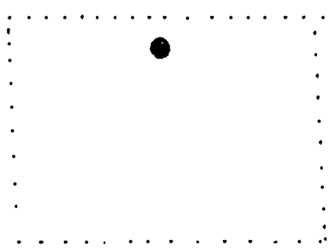
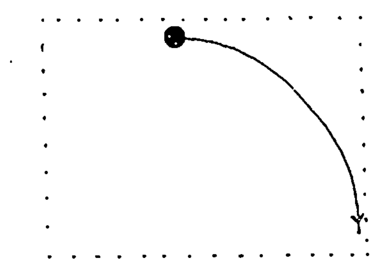
(e) $g\sin\theta$

Annex 2

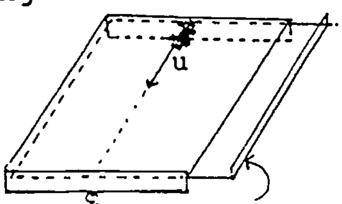
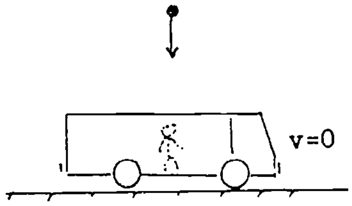
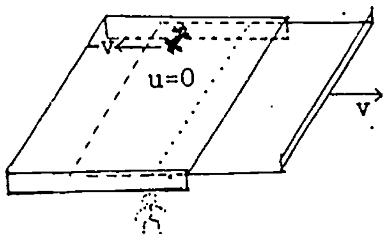
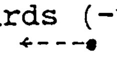
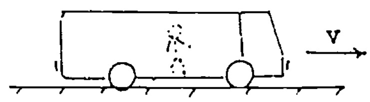
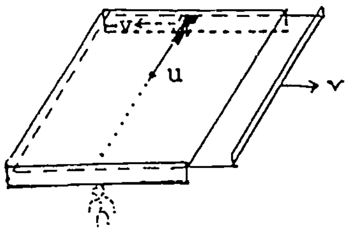
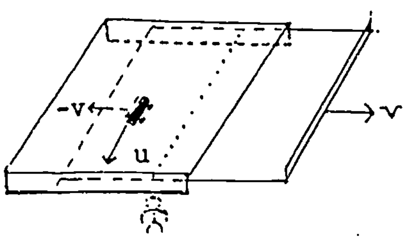
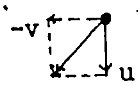
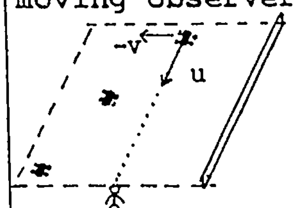
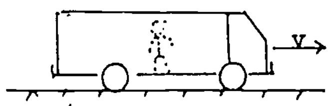
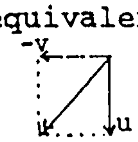
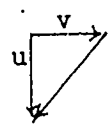
Addition of Vectors (1)

Prediction - Demonstratio	Explanation
Boat Crossing River  Observer (at rest) Current - Upper perspex Boat - toy-car What is the velocity/path of the boat to the observer?	When the velocity of the current is zero, the boat is seen to move across the river with velocity U as shown. 
 What is the velocity/path of the boat to the observer?	When the velocity of the current is V, the boat is seen to move along the bank with velocity V. 
  What is the velocity/path of the boat to the observer?	When the boat moves with velocity (u) while the current flows with velocity (v), the path seen by the observer as shown.  That is, the observer on the bank at rest would see the boat moving with resultant velocity $(\vec{u} + \vec{v})$ 

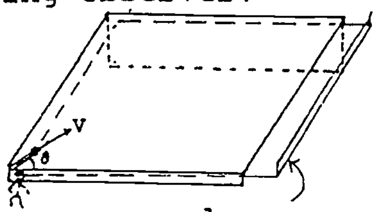
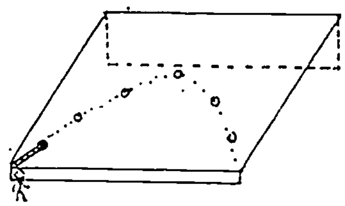
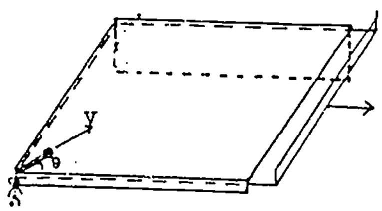
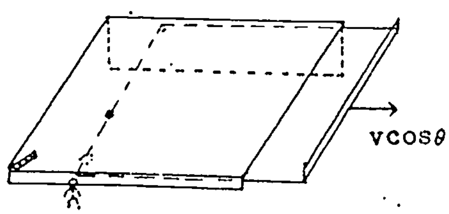
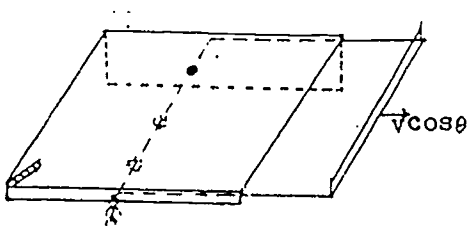
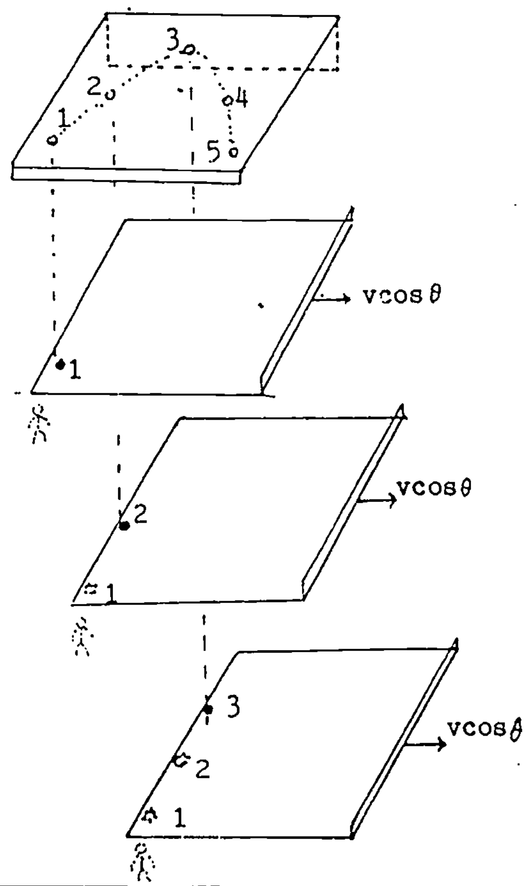
Addition of Vectors (2)

Prediction - Demonstration	Explanation
If you want to direct the boat crossing the river at point A as shown, in which direction the boat should be pointed?  	For direct crossing the river, the boat must have a component of $u\sin\theta$ which is equal in magnitude but opposite direction to the current v. 
Horizontal Projection  Switch on the electromagnet and let it move down the track. At the position as shown, switch off the electromagnet. Predict the path that the iron ball will travel.  (Consider the electromagnet and the iron ball as the helicopter and bomb respectively.)	When the electromagnet is switched off, the iron ball will drop but not vertically downwards since it has an initial horizontal-velocity v same as the electromagnet (Newton's First Law). The path traversed is a parabola as shown. 

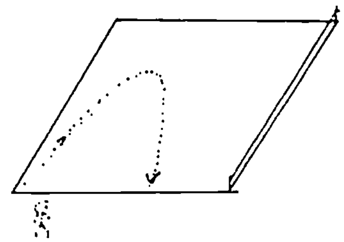
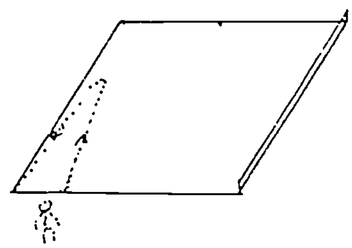
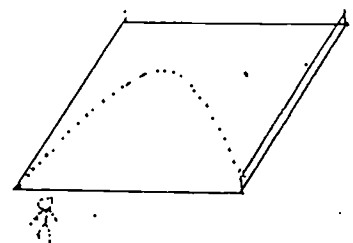
Subtraction of Vectors (1)

Prediction - Demonstration	Explanation
Rain drops seen by a moving observer  Observer - on lower perspex Rain drop - toy car What is the velocity/path of Rain drop as seen by the observer when the observer is at rest?	When the observer remains at rest, he should see the rain drops falling vertically downwards. 
 What is the velocity/path of the rain drop as seen by the observer when the observer is moving?	Suppose that the rain drop remains stationary, the moving observer (forwards, v) should see the rain drop moving backwards (-v)  
  What is the velocity/path of the rain drop as seen by the moving observer?	In actual case, to a moving observer, the rain drop has two velocity: (a) its own downward velocity (u), and (b) backward velocity (-v) as seen by the moving observer    The following vector diagrams are equivalent.   Resultant $= \vec{u} + (\vec{-v})$ Velocity of rain drop with respect to the moving observer $= \vec{u} - \vec{v}$

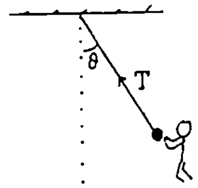
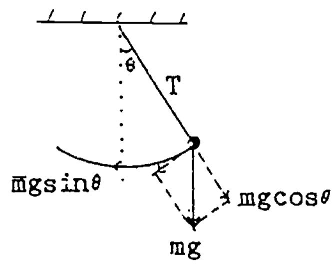
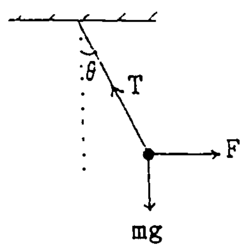
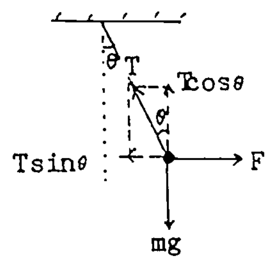
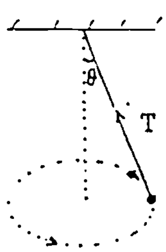
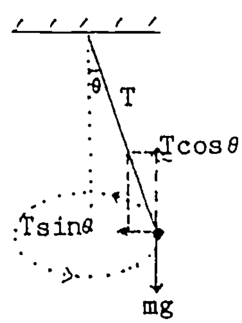
Subtraction of Vectors (2)

Prediction - Demonstration	Explanation
Projectile observed by a moving observer.  Observer: on lower perspex What is the path of the projectile seen by the observer when the observer remains at rest.	° When the observer remains at rest, he will see the projectile moving along a parabola path since the ball experiences a constant force downward along the inclined plane. 
 What is the path of the projectile as seen by the observer when the observer is moving with a velocity $v\cos\theta$?  	° Since the observer is moving with constant velocity $v\cos\theta$, there is no horizontal displacement between the projectile and the moving observer. ° To the moving observer, the projectile is just moving up and down along a vertical path. 

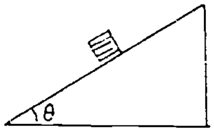
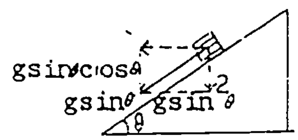
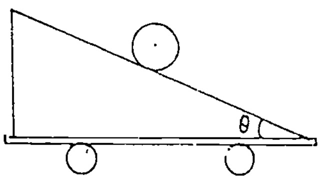
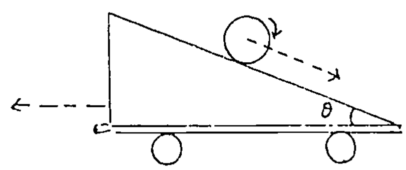
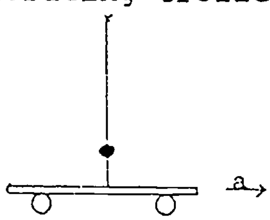
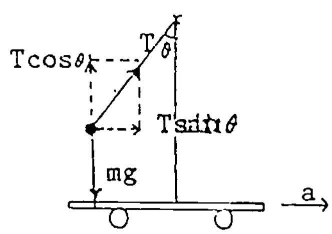
Subtraction of Vectors (3)

Prediction - Demonstration	Explanation
What is the path of the projectile as seen by the observer when the observer is moving with a velocity $v_0 < v\cos\theta$?	 A parabola with shorter range
What is the path of the prjectile as seen by the observer when the observer is moving with a velocity $v_0 > v\cos\theta$?	 A parabola with range on backward position
What is the path of the projectile as seen by the observer when the observer is moving with a v_0 along the backward direction?	 A parabola with longer range

Resolution of Vectors (1)

Prediction - Demonstration	Explanation
Simple Pendulum  when the bob is released, in which direction will the bob move? What is the value of the tension in the string?	° For dynamics motion, forces should be resolved into components which are parallel and perpendicular to the direction of motion of the body.  $T = mg\cos\theta$ $ma = mg\sin\theta$
Equilibrium  What is the tension in the string?	° At equilibrium, decomposition of the tension T into horizontal and vertical components is the simple way to solve the problem since T is the equilibrium force to the resultance of mg and force F.  $T = mg\ /\cos\theta$
Conical Pendulum  The bob is moving in a horizontal circle. What is the tension in the string?	° As the bob is in circular motion, it needs a centripetal force which can only be provided by the tension T.  $T\cos\theta = mg$ $T\sin\theta = mv^2/r$

Resolution of Vectors (2)

<table>
<tr><th>Prediction - Demonstration</th><th>Explanation</th></tr>
<tr><td>An object is moving down along an inclined plane
(A)

Is there any component of acceleration along the horizontal direction?</td><td>° The acceleration of the block is $g\sin\theta$ and its direction points downwards along the inclined plane. Thus the horizontal component of acceleration is $g\sin\theta \cos\theta$
</td></tr>
<tr><td>(B)

Will the trolley-incline system move when the ball is rolling down?
Is there any force acting horizontally and pushing the trolley-plane system move?</td><td>° The force pressing on the inclined plane has a horizontal component pushing the trolley-plane system accelerating along the backward direction.
</td></tr>
<tr><td>Pendulum on an accelerating trolley

When the trolley accelerates with a, what will happen to the bob? What is tension in the string?</td><td>° The bob will accelerates with a. Only T has a horizontal component to keep the bob accelerating.

$T\cos\theta = mg$
$T\sin\theta = ma$</td></tr>
</table>